ELSEVIER

Food Chemistry 69 (2000) 135–141

Food Chemistry

www.elsevier.com/locate/foodchem

Evaluation of antioxidant activity of some plant extracts and their application to ground beef patties

Esam H. Mansour*, Ali H. Khalil

Department of Food Science and Technology, Faculty of Agriculture, Menofiya University, 32516-Shibin El-Kom, Egypt

Received 11 June 1999; received in revised form 1 October 1999; accepted 1 October 1999

Abstract

The freeze-dried extracts from potato peels, fenugreek seeds and ginger rhizomes appeared to possess antioxidant activity against a β-carotene-linoleic acid emulsion. Ginger rhizome extract exhibited the highest antioxidant activity and had an activity comparable to commercial antioxidants, sustane 20 and sustane HW-4. The antioxidant activity of freeze-dried extracts from ginger rhizomes and fenugreek seeds was maximum at pH 7.0, while for potato peel extract, it was maximum at pH ranging from 5.0 to 6.0. Potato peel and fenugreek seed extracts were more heat-stable than ginger rhizomes extract. The antioxidant activity was not affected by storage in dark conditions at ~5, ~25 and 37°C over a period of 21 days, while a significant reduction was observed for extracts kept in light conditions at room temperature (~25°C). Additions of freeze-dried extracts from ginger rhizomes and fenugreek seeds to beef patties were more effective than potato peel extract in controlling lipid oxidation and color changes during cold storage.

1. Introduction

Lipid oxidation is a major cause of muscle food deterioration, affecting color, flavor, texture and nutritional value (Chan, Decher & Means, 1993; Kanner, Harel & Jaffe, 1991; Lee, Kim & Ashmore, 1986; Rhee, Anderson & Sams, 1996; Yin & Cheng, 1997). This oxidative deterioration of muscle involves the oxidation of the unsaturated fatty acids, catalyzed by hemoproteins as well as non-heme iron (Sato & Hegarty, 1971; Yin & Cheng). Addition of synthetic antioxidants, such as butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT) and tertiary butylhydroquinone (TBHQ) can control lipid oxidation in foods (Khalil & Mansour, 1998). However, the use of these synthetic antioxidants has begun to be restricted because of their health risks and toxicity (Buxiang & Fukuhara, 1997; Hirose, Takesada, Tanaka, Taman, Kato & Shirai, 1998). Therefore, the importance of replacing synthetic antioxidants with natural ingredients from oilseeds, spices and other plant materials has increased greatly. Some components of extracts isolated from fruits and vegetables have been proven in model systems, to be as effective antioxidants as synthetic antioxidants (Al-Saikhan, Howard & Miller, 1995; Loliger, 1989; Papadopoulos & Boskou, 1991; Pratt and Hudson, 1990; Rodriguez de Sotillo, Hadley & Holm, 1994). Several natural plant materials such as black pepper and propolis (Dessouki, El-Dashlouty, El-Ebzary & Heikal, 1980); rosemary (Cuvelier, Berset & Richard, 1994) and oriental herbs (Kim, Kim, Kim, Oh & Jung, 1994) have been reported to provide significant protection in freshly cooked meat and were effective in retarding lipid oxidation. However, natural antioxidant use has been limited due to high costs and color and flavor problems.

The present study addresses the utilization of economic plant materials such as potato peel, fenugreek seeds and ginger rhizomes as sources of natural antioxidants. Our objectives were to evaluate the antioxidant activity of extracts from potato peel, fenugreek seeds and ginger rhizomes and to study the stability (pH, heat and storage) of these extracts. The effectiveness of these extracts in preventing or reducing lipid oxidation, rancid odor and color changes of ground beef patties stored at ~5°C was also studied.

2. Materials and methods

Three different plant materials (potato peel, fenugreek seeds and ginger rhizomes) were used in this investigation

* Corresponding author. Tel.: +20-48-223942; fax: +20-48-223942.

0308-8146/00/$ - see front matter
PII: S0308-8146(99)00234-4

as a source of antioxidant. Tubers of King Edward potatoes (*Solanum tuberosum* L.) used in the study were obtained from the Vegetable Research Farm at Menofiya University, Shibin El-Kom, Egypt. The tubers were washed and peeled, using a kitchen vegetable peeler. The peels were dried at 50°C for 72 h in a convection-type oven (VEB MLW Medizinische, Gerete, Berlin, Germany).

Fenugreek seeds and ginger rhizomes were purchased from a local market in Alexandria, Egypt. Commercial antioxidants used in this study, sustane HW-4 (20% BHT and 20% BHA) and sustane 20 (20% TBHQ and 10% citric acid), were obtained from UOP Food Products and Processes (Des Plaines, IL, USA). Antrancine 350 (propyl gallate, TBHQ and citric acid) was obtained from Jan Dekker (Wormerveer, Netherlands). Thiobarbituric acid (TBA) was obtained from Aldrich Chemical Co. (Milwaukee, WI). All other chemicals used were of analytical grade and were obtained from Sigma Chemical Co (St. Louis, MO).

2.1. Preparation of antioxidant extracts

Dry potato peel, fenugreek seeds and ginger rhizomes were ground separately and passed through a 60 mesh screen. One hundred grams of each ground material were defatted by shaking three times with four volumes of petroleum ether in a rotary shaker (Julabo D-7633 Seelbach, Germany) for 1 h. The residues obtained after filtration were dried overnight under a hood until all traces of petroleum ether were removed. The dried residues from each material were extracted three times with four volumes of 90% ethanol by shaking for 1 h and filtered. The combined filtrates from each material were concentrated in a rotavapor (Rotvac evaporator RVO-64, Czechoslovakia) and placed under a hood to remove the residual ethanol. The obtained aqueous extracts were frozen overnight and freeze-dried at −60°C (Labconco Freeze Dry 64312, Kansas, MO). The freeze-dried extracts were stored in air-tight containers at 5°C until used for the determination of antioxidant activity.

2.2. Antioxidant activity

Antioxidant activities of freeze-dried extracts and commercial antioxidants (0.1 g/5 ml distilled water) were determined according to the procedure described by Taga, Miller and Pratt (1984). β-Carotene (2 mg) was dissolved in 20 ml of chloroform. A 3 ml aliquot of the solution was added to 40 mg linoleic acid and 400 mg tween 40. Chloroform was removed with a rotary evaporator at 50°C. Oxygenated distilled water (100 ml) was added to the β-carotene emulsion and mixed well. Antioxidant extract (0.12 ml) was mixed with oxygenated β-carotene emulsion (3 ml) and incubated at 50°C. Oxidation of the β-carotene emulsion was monitored spectrophotometrically at 470 nm after 10, 20 and 30 min incubation at 50°C. Distilled water was used instead of antioxidant extract as a control treatment. Degradation rate of extracts was calculated according to the following equation: Sample degradation rate = Ln $(a/b)\times 1/t$ where: Ln = natural log, a = initial absorbance at time 0, b = absorbance at 10, 20 and 30 min, t = time (min).

Antioxidant activity (AA) was expressed as percentage inhibition relative to the control using the following equation:

$$\mathrm{AA} = \frac{\text{Degradation rate of control} - \text{Degradation rate of sample}}{\text{Degradation rate of control}} \times 100$$

2.3. Heat, pH and storage stability

Antioxidant extracts were pre-incubated at different temperatures in the range of 40–100°C for 30 min. Antioxidant activity was determined as previously mentioned. Also, to evaluate the effect of boiling time on the antioxidant activity, the freeze-dried extracts were heated in a boiling water bath for 0, 30, 60, 90 and 120 min, and the residual antioxidant activity was determined. For pH stability, antioxidant extracts were pre-incubated at pH values in the range of 4.0–9.0 for 30 min. The residual antioxidant activity was determined. The antioxidant extract from each material was divided into four (10 ml) aliquots. The first three aliquots were stored in dark condition under refrigeration (∼5°C), room temperature (∼25°C) and 37°C. While the fourth aliquot was stored in light conditions at room temperature (∼25°C). Antioxidant activity was determined periodically over 3 weeks for each aliquot.

2.4. Preparation of ground beef patties

Ground beef patties were prepared from fresh lean beef and kidney fat obtained from Shibin El-Kom, Egypt. The lean beef and kidney fat were ground in a Hobart meat grinder (Model # 4046, Hobart Manufacturing Co., Troy, OH). Representative samples from the lean beef and fat were initially analyzed for fat content. Lean and fat sources were formulated and mixed to have 20% fat level. Beef patties were prepared to provide seven treatments. Control treatment was formulated without antioxidant. The other treatments were prepared by adding two levels (500 and 1000 ppm) from each antioxidant extract (potato peel, fenugreek seeds and ginger rhizomes). Each batch of treatment (48 ground beef patties) was hand-stuffed into fiber casing to form patties (about 1.2 cm thick and 10 cm diameter). Raw patties were placed on plastic foam meat trays, wrapped with polyethylene film and kept in a refrigerator at ∼5°C for 12 days.

2.5. Color evaluation

Color of raw patties was determined using a Lovibond Tintometer (The Tintometer LTD., Salisbury, UK). The readings were further converted into CIE units using visual density graphs and the instruction manual supplied with the apparatus.

2.6. Thiobarbituric acid (TBA)

TBA values were determined spectrophotometrically according to the procedure described by Siu and Draper (1978). Ten grams of sample were homogenized in 25 ml distilled water, then mixed with 25 ml of 10% trichloroacetic acid. The mixture was vortex-mixed and filtered. One milliliter of 0.06 M thiobarbituric acid was added to 4 ml aliquots of the filtrate and heated in a boiling water bath (10 min) for color development. The absorbance was measured at 532 nm using a Spectronic 2000 spectrophotometer. The TBARS values of antioxidant-treated patties were compared to control patties (without antioxidant). The TBARS values were expressed as mg malonaldehyde/kg sample.

2.7. Sensory properties

Sensory evaluation of stored patties was conducted to determine the presence of rancid meat odor. Evaluation was performed by eight panelists who were graduate students and staff members in the Department of Food Science and Technology, Menofiya University, Shibin El-Kom, Egypt. Panelists were selected on the basis of their interest and availability. Panelists were trained in two 1 h sessions in which they were served patties from a wide variety of treatments to familiarize them with a wide range of odor. Freshly prepared controls were made on the day of testing to be used as a reference odor. Samples were assigned randomly to each panelist and served warm (~40°C). Three repetitions from each treatment were served to each of the panelists during six separate sessions. Sensory scores were recorded utilizing a 6 point descriptive odor score. Descriptive terms used were absent, very slight, slight, moderate, strong and very strong. Numerical values were ranged from 0 (absent) to 6 (very strong).

2.8. Statistical analysis

Antioxidant activities of freeze-dried extracts from potato peel, fenugreek seeds, ginger rhizomes and commercial antioxidants were recorded as means ± standard deviation of triplicate measurements and were analyzed using completely randomized analysis of variance. Antioxidant stability (heat, pH and storage) as well as rancid odor, TBA values and color of ground beef patties stored at ~5°C for 12 days were analyzed using completely randomized factorial design (SAS, 1988). Three replicates were used for each effect and two determinations were conducted for each replicate. When a significant main effect was detected, the means were separated with the Student–Newman–Keuls test. Differences between treatments at 5% ($P \leqslant 0.05$) level were considered significant.

3. Results and discussion

Antioxidant activities of freeze-dried extracts from plant materials (potato peel, fenugreek seeds and ginger rhizomes) and commercial antioxidant are presented in Table 1. Extracts from fenugreek seeds and ginger rhizomes appeared to possess stronger antioxidant activities than those from potato peel. Antrancine 350 had the highest antioxidant activity among all commercial antioxidants as well as extracts from plant materials, while potato peel extract had the lowest activity. Onyeneho and Hettiarachchy (1993) reported that TBHQ and BHA-BHT had higher antioxidant activities than potato peel extract. Ginger rhizome extract had a stronger antioxidant activity than fenugreek seed extract, sustane 20 and sustane HW-4. Antioxidant activity of fenugreek seed extract was comparable to sustane HW-4.

The antioxidant activity of freeze-dried extracts was found to vary ($P \leqslant 0.05$) with pH (Fig. 1). The activity of fenugreek seed and ginger rhizome extracts gradually increased ($P \leqslant 0.05$) with maximum values at pH 7.0 followed by continuous decrease ($P \leqslant 0.05$) at alkaline pH. However, the activity of potato peel extract was maximum at pH values ranging from 5.0 to 6.0 then decreased ($P \leqslant 0.05$) at neutral and alkaline pH values. The reduction of antioxidant activity at alkaline pH might be attributed to either the loss of antioxidant property of the extracts or the enhancement of lipid

Table 1
Antioxidant activity[a] of freeze-dried extracts from potato peel, fenugreek seeds, ginger rhizomes and commercial antioxidants[b]

Tested material	Antioxidant activity
Potato peels	59.5 ± 0.81a
Fenugreek seeds	71.4 ± 0.80b
Ginger rhizomes	77.4 ± 0.68d
Sastane HW-4[c]	71.8 ± 0.67b
Sustane 20[d]	75.1 ± 0.93c
Antrancine 350[e]	85.3 ± 0.79e
LSD	1.40

[a] Antioxidant activity = % inhibition relative to control.
[b] Means in the same column with different letters are significantly different ($P \leqslant 0.05$).
[c] Sustane HW-4 = 20% BHT and 20% BHA.
[d] Sustane 20 = 20% TBHQ and 10% citric acid.
[e] Antrancine 350 = propyl gallate, TBHQ and citric acid.

oxidation. Lee, Hargus, Kirkpatrick, Berner and Forsythe (1975) reported that oxygen uptake rate increased two and four times at pH 7.5 and 8.0, respectively. Liu (1970) reported that hemoprotein-catalyzed oxidation is most active at alkaline pH.

Figs. 2 and 3 show the effects of temperature on the antioxidative stability of freeze-dried extracts from potato peel, fenugreek seeds and ginger rhizomes. The antioxidant activity was constant for ginger rhizome extract when incubated at a temperature ranging from 40 to 60°C for 30 min. However, for potato peel and fenugreek seed extracts, the antioxidant activities were stable when incubated at 40–80°C for 30 min. Incubating ginger extract at higher than 60°C, and potato peel and fenugreek seed extracts at higher than 80°C for 30 min, resulted in a significant ($P \leqslant 0.05$) decrease in antioxidant activities. Heating at 100°C for 30 min reduced ($P \leqslant 0.05$) the antioxidant potency of ginger, fenugreek and potato peel extracts by 25, 15 and 12%, respectively.

Increasing the time of boiling resulted in a significant ($P \leqslant 0.05$) decrease in the antioxidant activity of the freeze-dried extracts (Fig. 3). The reduction in the antioxidant activity for ginger rhizome extract was more pronounced than those for potato peel and fenugreek seed extracts at each time of boiling. The results indicated that antioxidants in potato peel and fenugreek seed extracts were fairly heat-stable with 63.2 and 58.0% activity, respectively, still remaining after 120 min heating at 100°C. However, the remaining antioxidant activity in ginger rhizome extract was about 28% after 120 min heating at 100°C.

Freeze-dried extracts from potato peel, fenugreek seeds and ginger rhizomes stored in the dark at ~5, ~25 and 37°C over a 21 day period did not show any change in the antioxidant activity (Table 2). However, extracts stored in light conditions at room temperature (~25°C) showed significant ($P \leqslant 0.05$) reduction in the antioxidant potency after 7 days storage (Table 3). This reduction is attributed to the light effect. Similar results were reported by Rodriguez de Sotillo et al. (1994) who indicated that the phenolic acids in potato peel extract were degraded into other compounds during storage at room temperature. The highest reduction was observed for potato peel extract (12.1%) followed by fenugreek extract (8.9%) and ginger extract (2.4%). There was a significant ($P \leqslant 0.05$) reduction in the antioxidant activity from day 7 to day 21 of storage in light at ~25°C.

Addition of freeze-dried extracts from potato peel, fenugreek seeds and ginger rhizomes to beef patties reduced ($P \leqslant 0.05$) the rancid odor scores compared to

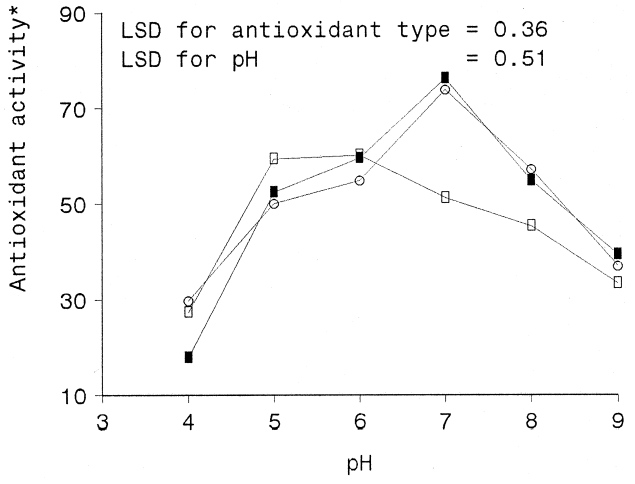

Fig. 1. Effect of pH on antioxidant activity of freeze-dried extracts from potato peel, fenugreek seeds and ginger rhizomes. □ Potato peel, ○ fenugreek seeds, ■ ginger rhizomes, * % inhibition relative to control.

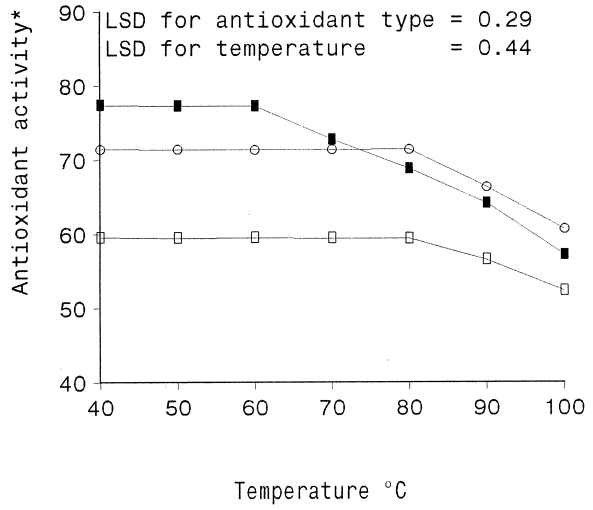

Fig. 2. Effect of temperature on antioxidant activity of freeze-dried extracts from potato peel, fenugreek seeds and ginger rhizomes. □ Potato peel, ○ fenugreek seeds, ■ ginger rhizomes, * % inhibition relative to control.

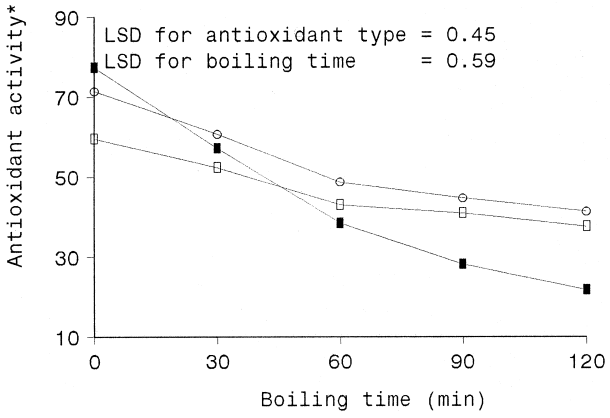

Fig. 3. Effect of boiling for different times on antioxidant activity of freeze-dried extracts from potato peel, fenugreek seeds and ginger rhizomes. □ Potato peel, ○ fenugreek seeds, ■ ginger rhizomes, * % inhibition relative to control.

control (Table 4). Patties treated with freeze-dried extracts from ginger rhizomes and fenugreek seeds received lower ($P \leqslant 0.05$) panel scores than those treated with freeze-dried extract from potato peel. These results indicated that the freeze-dried extracts from ginger rhizomes and fenugreek seeds were effective in reducing the oxidative deterioration of fat in beef patties throughout the cold storage. Wu and Brewer (1994) reported that ground beef containing antioxidant from soy protein isolate had less rancid odour than a control. Barbut, Josephson and Maurer (1985) and Spanier, Miller and Bland (1992) found that hexanal and total volatiles were highly correlated with sensory evaluations of rancid odor of meat products. The rancid odor score increased ($P \leqslant 0.05$) as the storage period progressed, regardless of the antioxidant treatment used. At the end of the storage period (12 days), control sample and patties treated with antioxidant from potato peel had scores in the range of strong rancid odor, while those treated with antioxidants from fenugreek seeds and ginger rhizomes

Table 2
Effect of different storage conditions on antioxidant activity of freeze-dried extracts from potato peel, fenugreek seeds and giner rhizomes

Storage time (days)	Storage in dark conditions									
	~5°C			~25°C			37°C			Mean[a]
	Potato	Fenugreek	Ginger	Potato	Fenugreek	Ginger	Potato	Fenugreek	Ginger	
0	59.5	71.4	77.4	59.5	71.4	77.4	59.5	71.4	77.4	69.4a
7	59.4	71.4	77.3	59.5	71.4	77.4	59.4	71.3	77.2	69.4a
14	59.4	71.4	77.3	49.4	71.4	77.4	59.5	71.4	77.4	69.4a
21	59.5	71.4	77.3	59.5	71.4	77.3	59.4	71.4	77.3	69.4a
Mean[b]		69.4a			69.4a			69.4a		

[a] Means in the same column with different letters are signficantly different ($P \leqslant 0.05$), LSD = 0.73.
[b] Means in the same row with different letters are signficantly different ($P \leqslant 0.05$), LSD = 0.65.

Table 3
Effect of storage in light at ~25°C on antioxidant activity of freeze-dried extracts from potato peel, fenugreek seeds and ginger rhizomes

Storage time (days)	Potato peel	Fenugreek seeds	Ginger rhizomes	Mean[a]
0	59.5	71.4	77.4	69.4a
7	53.1	66.6	75.8	65.2a
14	52.4	65.5	75.6	64.5a
21	52.3	65.1	75.5	64.3a
Mean[b]	54.3a	67.2b	76.1b	

[a] Means in the same column with different letters are signficantly different ($P \leqslant 0.05$), LSD = 0.92.
[b] Means in the same row with different letters are signficantly different ($P \leqslant 0.05$), LSD = 1.03.

Table 4
Effect of different concentrations of freeze-dried extracts from potato peel, fenugreek seeds and giner rhizomes on rancid odor[a] or raw beef patties during cold storage at ~5°C for 12 days

Storage time (days)	Treatment							Mean[b]
	Control	Potato peel		Fenugreek seeds		Ginger rhizomes		
		500 ppm	1000 ppm	500 ppm	1000 ppm	500 ppm	1000 ppm	
0	0.52	0.50	0.52	0.52	0.50	0.50	0.51	0.51a
4	2.35	2.10	1.96	1.44	1.32	1.38	1.20	1.68b
8	3.59	3.17	2.91	1.89	1.78	1.83	1.62	2.40c
12	4.98	4.18	4.02	2.32	2.26	2.19	2.02	3.14d
Mean[c]	2.86c	2.49b	2.35b	1.54a	1.47a	1.48a	1.34a	

[a] Mean based on a six-point scale where 0 = absent, 1–1.5 = very slight, 1.5–3 = slight, 4 = moderate, 5 = strong and 6 = very strong.
[b] Means in the same column with different letter are signficantly different ($P \leqslant 0.05$), LSD = 0.13.
[c] Means in the same row with different letters are signficantly different ($P \leqslant 0.05$), LSD = 0.21.

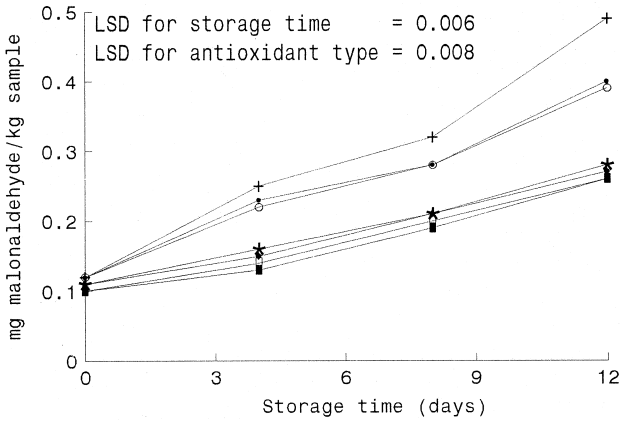

Fig. 4. Effect of antioxidant from potato peel, fenugreek seeds and ginger rhizomes on TBA values of raw beef patties stored at 5°C for 12 days. + control, ● P500, ○ P1000, * F500, ◆ F1000, □ G500, ■ G1000.

had scores in the range of slight rancid odor and are considered the most acceptable treatments throughout the cold storage period.

TBA values of raw beef patties were affected ($P \leqslant 0.05$) by storage periods and antioxidant treatments (Fig. 4). Overall mean TBA values of raw patties containing freeze-dried extracts from ginger rhizomes, fenugreek seeds and potato peel were lower ($P \leqslant 0.05$) than the control. Also, there were no significant ($P > 0.05$) differences in TBA values between 500 and 1000 ppm for all freeze-dried extracts. Ginger rhizome extract gave the best protection against lipid oxidation among all treatments. TBA values of all treatments increased ($P \leqslant 0.05$) as storage period progressed. Similar results were reported by Khalil and Mansour (1998) during storage of carp fillets at 5°C for 16 days. Although initial values were low, a rapid increase occurred in control samples throughout the storage periods, while much slower rate and little changes in TBA values were observed in patties treated with antioxidant from fenugreek seeds and ginger rhizomes. These results are in agreement with those obtained by Hettiarachchy, Glenn, Gnanasambandam and Johnson (1996) and Akamittath, Brekke and Schanus (1990) who reported the effectiveness of synthetic and natural antioxidants in controlling lipid oxidation in meat products.

Color attributes of raw patties (Table 5) are expressed in terms of dominant hue wavelength (color itself), brightness (lightness or value), saturation (chroma) and visual density ($-\log_{10}$ brightness÷100). Patties formulated with antioxidant had higher ($P \leqslant 0.05$) red colors than the control. This could be due to the antioxidant protecting color by retarding the formulation of metmyoglobin. Also, patties prepared with antioxidant from fenugreek seeds and ginger rhizomes exhibited higher ($P \leqslant 0.05$) red colors than those prepared with antioxidant from potato peel. The red color was significantly ($P \leqslant 0.05$) decreased by increasing the storage period. The visual density values of patties formulated with antioxidant were lower ($P \leqslant 0.05$) than the control. The low values of visual density show a tendency toward a lighter color compared to the control. Patties prepared with antioxidant from potato peel were darker than those prepared with antioxidant from fenugreek seeds and ginger rhizomes. It is worthy of mention that the antioxidant activity of potato peel extract was maximum at pH values ranging from 5.0 to 6.0 (Fig. 1) which is below the pH of the ground beef. Therefore, its effect in protecting color by inhibiting the oxidation of myoglobin was very low. Also, data indicated that visual density increased ($P \leqslant 0.05$) as storage period increased.

The brightness of patties followed a trend opposite to that for visual density. The dominant hue wavelength of patties ranged from 599 to 606 nm, indicating that the general color of all treatment lay in the area bounded by the red and yellow lines on the spectrum locus of the chromaticity diagram.

The saturation values of patties treated with antioxidant were lower ($P \leqslant 0.05$) than the control. Similar results were obtained by Hettiarachchy et al. (1996) who observed that patties containing TBHQ had lower saturation values and higher red colors than the control.

Table 5
Color properties of beef patties as affected by antioxidant type, antioxidant level and cold storage at ~5°C for 12 days[a]

Property	Antioxidant type			LSD	Antioxidant level (ppm)			LSD	Storage time (days)				LSD
	Potato peel	Fenugreek seeds	Ginger rhizomes		0	500	1000		0	4	8	12	
Red	4.48a	4.62b	4.67c	0.047	4.45a	4.66b	4.66b	0.047	4.90d	4.74c	4.48b	4.23a	0.054
Yellow	1.48c	1.35b	1.28a	0.047	1.55b	1.28a	1.28a	0.047	1.10a	1.23b	1.44c	1.71d	0.054
Blue	1.15b	1.05a	1.05a	0.047	1.15b	1.05a	1.05a	0.047	0.90a	0.90a	1.17b	1.37c	0.054
Visual density	0.23c	0.22b	0.21a	0.004	0.24b	0.21a	0.21a	0.004	0.19a	0.22b	0.23c	0.25d	0.005
Brightness (%)	58.33a	59.65b	60.58c	0.32	57.68a	60.44b	60.44b	0.32	63.83d	60.05c	57.95b	56.25a	0.36
Dominant hue wave length (nm)	602.0a	602.8b	603.3c	0.47	601.0a	603.6b	603.6b	0.47	606.0d	603.7c	602.0b	599.2a	0.54
Saturation (%)	20.51c	19.23b	18.66a	0.18	21.40b	18.50a	18.50a	0.18	15.17a	18.32b	21.10c	23.27d	0.21

[a] Means in the same row with different letters are significantly different ($P \leqslant 0.05$) for each effect (antioxidant type, antioxidant level and storage time).

From the results, it could be concluded that freeze-dried extracts from potato peel, fenugreek seeds and ginger rhizomes exhibited potent antioxidant activity against a β-carotene–linoleic emulsion system. The antioxidant activity of these extracts was comparable to commercial antioxidants. Additions of freeze-dried extracts from ginger rhizomes and fenugreek seeds (at 500 ppm) to beef patties were found to be effective in retarding rancid odor, TBA, and color change. The fenugreek seeds and ginger rhizomes, as natural plant materials, might be promising sources of natural antioxidants for use in meat products.

References

Akamittath, J. G., Brekke, C. J., & Schanus, E. G. (1990). Lipid oxidation and color stability in restructured meat systems during frozen storage. *Journal of Food Science, 55*, 1513–1517.

Al-Saikhan, M. S., Howard, L. R., & Miller, J. C. (1995). Antioxidant Activity and total phenolics in different genotypes of potato (*Solanum Tuberosum*, L). *Journal of Food Science, 60*, 341–343.

Barbut, S., Josephson, D. B., & Maurer, A. J. (1995). Antioxidant properties of rosemary oleoresin in turkey sausage. *Journal of Food Science, 50*, 1356–1359.

Buxiang, S., & Fukuhara, M. (1997). Effects of co-administration of butylated hydroxytoluene, butylated hydroxyanisole and flavonoide on the activation of mutagens and drug-metabolizing enzymes in mice. *Toxicology, 122*, 61–72.

Chan, K. M., Decker, E. A., & Means, W. J. (1993). Extraction and activity of carnosine, a naturally occurring antioxidant in beef muscle. *Journal of Food Science, 58*, 1–4.

Cuvelier, M. E., Berset, C., & Richard, H. (1994). Antioxidant constituents in sage (*Salvia officinalis*). *Journal of Agricultural and Food Chemistry, 42*, 665–669.

Dessouki, T. M., El-Dashlouty, A. A., El-Ebzary, M. M., & Heikal, H. A. (1980). Propolis and some other natural antioxidants for fats of frozen meat. *Agricultural Research Review, 58*, 311–320.

Hettiarachchy, N. S., Glenn, K. C., Gnanasambandam, R., & Johnson, M. G. (1996). Natural antioxidant extract from fenugreek (*Trigonella foenumgraecum*) for ground beef patties. *Journal of Food Science, 61*, 516–519.

Hirose, M., Takesada, Y., Tanaka, H., Tamano, S., Kato, T., & Shirai, T. (1998). Carcinogenicity of antioxidants BHA, caffeic acid, sesamol, 4-methoxyphenol and catechol at low doses, either alone or in combination and modulation of their effects in a rat medium-term multi-organ carcinogensis model. *Carcinogenesis, 19*, 207–212.

Kanner, J., Harel, S., & Jaffe, R. (1991). Lipid peroxidation of muscle food as affected by NaCl. *Journal of Agricultural and Food Chemistry, 39*, 1017–1021.

Khalil, A. H., & Mansour, E. H. (1998). Control of lipid oxidation in cooked and uncooked refrigerated carp fillets by antioxidant and packaging combinations. *Journal of Agricultural and Food Chemistry, 46*, 1158–1162.

Kim, S. Y., Kim, J. H., Kim, S. K., Oh, M. J., & Jung, M. Y. (1994). Antioxidant activities of selected oriental herb extracts. *Journal of the American Oil Chemists' Society, 71*, 633–640.

Lee, Y. B., Hargus, G. L., Kirkpatrick, J. A., Berner, D. L., & Forsythe, R. H. (1975). Mechanism of lipid oxidation in mechanically deboned chicken meat. *Journal of Food Science, 40*, 964–969.

Lee, Y. B., Kim, Y. S., & Ashmore, C. R. (1986). Antioxidant property in ginger rhizome and its application to meat products. *Journal of Food Science, 51*, 20–23.

Liu, H. (1970). Catalysts of lipid peroxidation in meats I. Linoleate peroxidation catalyzed by Metmb or Fe (II)-EDTA. *Journal of Food Science, 35*, 590–595.

Loliger, J. (1989). Natural antioxidants. In J.C. Allen & Hamilton, R. J., *Rancidity in foods*, London: Elsevier Applied Science.

Onyeneho, S. N., & Hettiarachchy, N. S. (1993). Antioxidant activity, fatty acids and phenolic acids compositions of potato peels. *Journal of the Science of Food Agriculture, 62*, 345–350.

Papadopoulos, G., & Boskou, D. (1991). Antioxidant effect of natural phenols on olive oil. *Journal of the American Oil Chemists' Society, 68*, 669–671.

Pratt, D. E. & Hudson, B. J. F. (1990). Natural antioxidants not exploited commercially. In B.J.F. Hudson, *Food antioxidants*. London: Elsevier Applied Science.

Rhee, K. S., Anderson, L. M., & Sams, A. R. (1996). Lipid oxidation potential of beef, chicken and pork. *Journal of Food Science, 61*, 8–12.

Rodriguez de Sotillo, D. R., Hadley, M., & Holm, E. T. (1994). Phenolics in aqueous potato peel extract: Extraction, identification and degradation. *Journal of Food Science, 59*, 649–651.

SAS (1988). *SAS users guide; basics, version 5*. Cary, NC: SAS Institute Inc.

Sato, K., & Hegarty, G. R. (1971). Warmed-over flavour in cooked meat. *Journal of Food Science, 36*, 1098–1102.

Siu, G. M., & Draper, H. H. (1978). A survey of the malonaldehyde content of retail meats and fish. *Journal of Food Science, 43*, 1147–1149.

Spanier, A. M., Miller, J. A. & Bland, J. M. (1992). Lipid oxidation: effect on meat proteins. In A. J. St.Angelo, *Lipid oxidation in food*, ACS Symposium, Series 500. Washington, DC: ACS Books, Inc.

Taga, M. S., Miller, E. E., & Pratt, D. E. (1984). Chia seed as a source of natural lipid antioxidants. *Journal of the American Oil Chemists' Society, 61*, 928–931.

Wu, S. Y., & Brewer, M. S. (1994). Soy protein isolate antioxidant effect on lipid peroxidation of ground beef and microsomal lipids. *Journal of Food Science, 59*, 702–706.

Yin, M. C., & Cheng, W. S. (1997). Oxymyoglobin and lipid oxidation in phosphatidylcholine liposomes retarded by α-tocopherol and β-carotene. *Journal of Food Science, 62*, 1095–1097.